THE TERRIER

M. R. Kelley

a capsule history of missile development

The history of the Applied Physics Laboratory between mid-1948 and mid-1956 was characterized by significant technological achievement, an outstanding part of which was the successful development of the missile named Terrier I. This was the first sea-going antiaircraft guided missile in world history. The Laboratory had, prior to that time, pursued an exploratory research and development program that resulted in, among other things, a supersonic-missile, test-vehicle configuration. The Navy decided to adapt it to tactical use as a rocket-propelled surface-to-air missile for the Fleet. This decision was communicated to the Guided Missiles Committee of the Department of Defense Research and Development Board on June 11, 1948. Dr. R. B. Kershner of APL proposed the name "Terrier" for the new missile, after the canine breeds of relatively small size, aggressive and tenacious by nature, but readily controlled by their masters. This name was approved by the Chief of the Bureau of Ordnance on December 29, 1948.

Development of Terrier presented no major problem in propulsion because enough was known of rocket propellants to afford confidence that it could attain the speed, altitude, and range demanded. However, there were other problems. Even though roll stabilization—a prerequisite of good beam-riding — had been achieved earlier by both subsonic and supersonic test models, and satisfactory beam-riding had already been demonstrated, unexpected difficulties were encountered in the first two STV*–3 flight tests (April and July, 1948). These tests had among their principal objectives the measurement of roll moment and determination of the damping coefficient, information that was urgently needed before a vehicle that incorporated a device for roll stabilization could be tested. Neither test provided the desired data because of malfunctions in the telemetering equipments, cause unknown.

In October 1948, a third test having these same objectives produced good roll data. Confirmatory results were also obtained in another flight test a month later. Shortly thereafter flights of two modified STV–3's, which were intended to be roll-stabilized, proved unsuccessful because of an apparent electrical power failure in one case and, in the other, the occurrence of large acceleration forces at end of boost, which were shown in post-flight analysis to have been present also in two previous STV–3 tests. Such forces had not been encountered in tests of the STV–2's. After careful study of the differences between the two vehicles, the booster-missile attachment was redesigned to minimize the possibility of a collision between it and the missile's tail

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These historical notes are adapted from a chapter on the Terrier missile prepared by Rear Admiral M. R. Kelley, U.S. Navy (Ret.) for inclusion in a history of the Applied Physics Laboratory.

* Supersonic test vehicle.

compartment and nozzle extension tube during separation. But the first flight test of this attachment (April 1949) showed that it had not resolved the difficulty; the missile did not roll-stabilize, and a violent disturbance occurred at separation, knocking out half the telemetering channels. Further investigation identified three acceleration forces operating during the boost and separation stage: (1) *acceleration at boost,* which forced the 250-pound sustainer charge rearward against the after face of the case; (2) *deceleration at end of boost,* which thrust the charge hard against the forward face of the case; and (3) *igniter pressure at ignition,* which drove the charge solidly against the after face of the case, producing the damaging shock. Accordingly it was decided to immobilize sustainer charges in all subsequent STV–3's, a "fix" that proved highly effective in later tests.

Meanwhile, during the above tests extending over a period of 18 months, progress was made in two other areas. A so-called "zero-length" launcher was checked out satisfactorily in four of the above-cited tests, and capture of the missile into the guidance beam at end-of-boost was successfully accomplished in the flight of an STV–2.

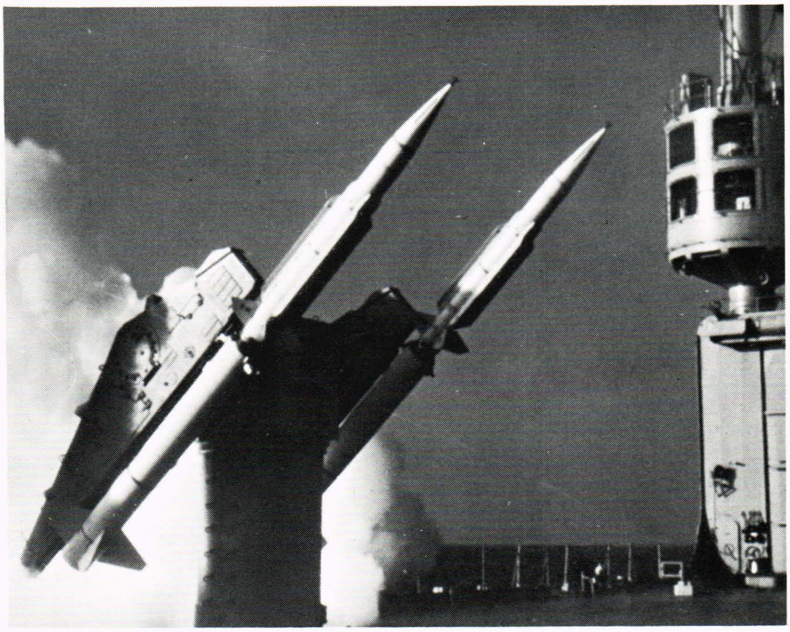
Prototype Testing Begins

Following the Navy's decision in the spring of 1948 to make a tactical missile of the STV–3, plans were formulated to reach the final design of the new missile through tests of a succession of prototype missiles designated Lots 1, 2, 3, 4, 5, and 7. Lots 6 and 8 were earmarked for development of a higher performance missile at a later date, to benefit from the experience with the earlier lots and from advances in the state of the art. Confident that a tactical version of the STV–3 could be achieved, the Navy early contracted with the Consolidated Vultee Aircraft Corporation for production of a pre-prototype Lot 0 consisting of fifteen missiles. Late in 1949, the Bureau of Ordnance (BuOrd) declared the Terrier to be in the production prototype stage and contracted with the above corporation for the manufacture and delivery of 50 prototype units spread over Lots 1 through 4. Pending delivery of the first Lot 0 missiles, tests of various models of the STV–3 were continued, these tests varying in their objectives as determined by the problems under investigation.

Guidance Problems Investigated

With completion of successful tests of the zero-length launcher and the achievement of roll stabilization in the STV–3, emphasis was more and more centered on solution of the guidance problem. This was at first a matter of beam-riding performance. The very modest effort on an interferometer homing system that had been started in 1948 was viewed only as a possible alternative in case satisfactory beam-riding guidance should prove unattainable. There had been early tests, beginning with two flights of subsonic control test vehicles in 1947 and followed by two successful STV flights in 1948, which inspired confidence that beam-riding guidance could be made effective for tactical employment afloat. In these tests, however, the radar guidance beam had been fixed in space and the test missile was so launched as to be in, or close to, the beam axis at the time of booster separation. This insured that the missile would be in a position to receive guidance signals from the radar. It was obvious that such an accommodation would only accidentally, if ever, occur in a tactical situation at sea.

In another respect, also, these tests were not representative of guidance conditions in actual service afloat. There the radar pulses directed at a high-speed aircraft would be reflected randomly from different surfaces or features of the target and, in combination with random reflections from the sea, would cause the beam to jitter. No beam-riding guidance system could be considered acceptable until a determination had been made that this jitter did not adversely affect the missile's accuracy in guided flight. The opportunity was taken, therefore, in the STV–2 test in April, 1949, marking the first successful use of a capture beam, to test also the missile's ability to ride a jittering beam. Jitter was injected into the beam at the radar source so as to simulate that expected in a tactical situation. Another "first" was achieved when the missile demonstrated in this test that it could ride a jittering beam with acceptable accuracy.

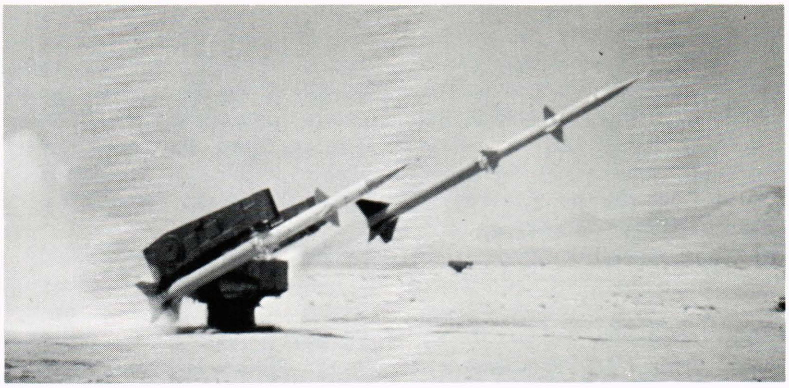


Terrier missiles (BT-3) being fired from the deck of the USS *Norton Sound.*

Meanwhile research and development in beam-riding guidance had been actively carried on with a view to improving the sensitivity of the missile response to control corrections for guidance errors, both near the surface and at altitude. Obviously, the aerodynamic control surfaces would have to be moved through greater angles in the rarified atmosphere at high altitude than in the denser atmosphere near the earth's surface in order to correct promptly any off-beam error. A redesign of the control system for the STV–3 had been completed near the end of 1948, the effectiveness of which was impressively demonstrated in a flight test about a year later when guidance sensitivity was changed in flight for the first time, being increased by a factor of six. The missile responded promptly by closing to within 2 mils of beam center, where it remained more than twice as long as any previous Bumblebee beam rider. This signaled an important advance in beam-riding accuracy. Other less obvious factors also had to be taken into account in devising a system of controlling missile guidance sensitivity, but results achieved in the above test indicated good progress. They were soon well corroborated by another STV–3 test that demonstrated excellent roll stabilization and speed of response.

In December 1949 the first of the initial experimental production missiles (Lot 0) was delivered and, within two months, was flight-tested at the Naval Ordnance Test Station (NOTS). Missile capture was most impressive, and beam-riding proved quite good during much of the flight. Since the Navy had already decided to use the aircraft tender USS *Norton Sound* for preliminary shipboard tests of Terrier, the opportunity was now taken to measure the effect of booster blast on a specially constructed deck section similar to that in the location selected for the ship's launcher. Results showed the deck to be suitable for launching Terrier at quadrant elevations of 35° or less.

Necessary preparations for shipboard testing included the assembly of all the elements of the Terrier system for installation in the ship, plus the elements of an approximately identical system for use at NOTS. The latter system, obviously, did not need to have the capabilities in the weapon-direction, fire-control, and launching subsystems that would be required in the face of the unpredictable motions of the ship at sea.



Test firing of the Terrier missile at China Lake, California.

By this time progress made toward a rocket-propelled tactical missile, plus the general advance on all fronts in missile technology, warranted an updated appraisal of the capabilities that seemed possible of attainment in an advanced design. Accordingly, in May 1950 the Navy issued a new operational requirement which set the military characteristics for a higher performance missile that came to be known as Terrier II. The Laboratory, which had contributed to the appraisal of capabilities pertinent to an improved Terrier missile, immediately undertook the necessary studies to formulate specifications for a design aimed at meeting the new requirements.

Action in Korea

But in a matter of weeks there occurred totally unexpected events of great historical importance, which gave new emphasis to the revolution in weapons and created overnight a sense of urgency that had not existed since V–J day. The "cold war" suddenly and unexpectedly came almost to the boiling point. A strong force of North Koreans, behind a phalanx of tanks, invaded South Korea on June 24. The U.N. Security Council in emergency session—in the absence of Russian representatives—adopted a resolution before the day was out condemning this unprovoked aggression, and three days later adopted a second resolution recommending that members of the United Nations furnish such assistance to the Republic of South Korea as might be necessary to restore the status quo in Korea. In compliance President Truman at once directed the U.S. Navy and the U.S. Air Force to give the South Koreans air cover and support; by June 30 U.S. military forces present in the area were quite fully committed.

Fear that the *police action*—so-called by President Truman—might escalate into a major war became a matter of utmost concern to all Americans. Each of the military Services immediately undertook a survey of its overall preparedness to meet such a contingency. This was backed up by individual and collective planning to blunt the edge of any further aggression before it could acquire momentum. As in World War II, the threat from the air, whether in the form of aircraft-launched guided rockets or surface-launched bombardment missiles, was considered most serious of all. This was fully substantiated by the Armed Services' research and development efforts that from 1945 were directed toward an adequate defense against such attack. Although there were several promising development programs, it was recognized that as of the start of hostilities in Korea no surface-to-air or air-to-air missile could be expected to reach the service-use stage in less than three years. Within the Department of Defense, after "in-house" surveys of the situation by the military Services, the following views found general acceptance: (1) the antiaircraft missile programs nearest the service-use stage should be pushed at the highest possible level of effort, compatible with the state of the art and good engineering practice, toward acceptance and production for use in combat; and (2) the number of missile programs might well be cut back, permitting continuation of only those that promised to satisfy requirements for which no other adequate program was in hand.

On October 25 Mr. K. T. Keller of the Chrysler Corporation was appointed Director of Guided Missiles by the Secretary of Defense. His mission, essentially, was to direct the military missile program so as to expedite entry into service use of those missile systems most urgently needed. Additional funds, facilities, and technical personnel were expected to be made available from the defense budget and by cutting back other programs less far advanced.

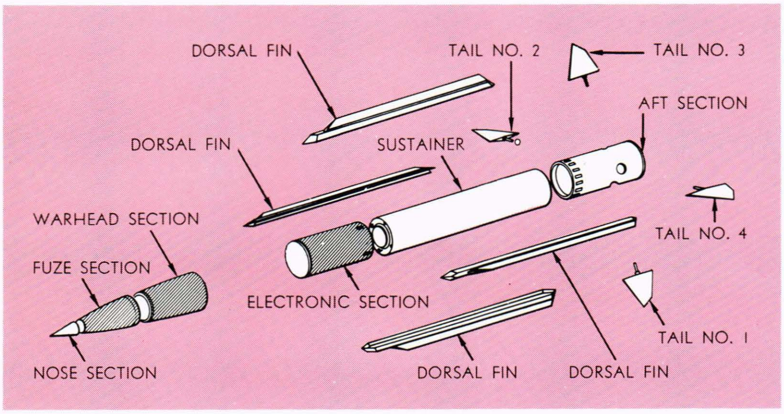
Missile Programs Accelerated

With a staff of civilian-military representatives of the three Services, Keller made a survey of all the guided missile programs and subsequently recommended for special emphasis the Army's Nike, the Navy's Terrier and the Navy's Sparrow, on the basis that each could be put into service at a relatively early date and each would satisfy an immediate need. Within the Research and Development Board of the Department of Defense, the treatment proposed for these three missiles was commonly called "super-acceleration," but in the fellowship of scientists, engineers, executives and administrators engaged in research, test, development, and production of guided missiles it was known as "Kellerization."

An almost immediate result of this treatment prescribed for the Terrier was a decision by BuOrd to have incorporated in the design of the Lot 4 prototype the final tactical features of Lot 7. The latter had been viewed originally as the ultimate production-engineered version of the tactical Terrier. The design of Lot 4, completed in conformity with that decision, was frozen at the end of 1950, anticipating that a satisfactory tactical missile would emerge thereby at least six months earlier than had been previously scheduled.

In addition to acceleration of the missile programs, the Navy decided to install Terrier systems in selected World War II heavy cruisers. Two dual launchers were to be located on the cruiser's after deck, each supplied from its missile magazine below by means of automatic handling and loading equipment. The subsystems needed for controlling two complete missile systems were also to be installed, making it possible for each launcher to fire a two-missile salvo every 30 seconds. The U.S. Marine Corps undertook at once to organize missile battalions for defense of overseas bases. Steps were also initiated by the Army to procure 25 Terriers for training purposes, and preliminary action was taken to have the supporting ground control equipment provided. This resulted early in 1951 in a contract with the Radio Corporation of America to develop an Army Tactical Terrier System. At NOTS a Terrier system similar to that planned for the USS *Norton Sound,* but not suited for use at sea, was installed by mid-1950 and put in operation in the flight-test program. By the end of the year installation of the first Terrier shipboard system, including computer and dual launcher, was completed in the *Norton Sound* at the San Francisco Naval Shipyard. Navy Guided Missile Training Unit No. 21 was transferred from NOTS to the ship for on-board training and checkout of the system in preparation for the first missile firing afloat, which was expected to take place within a few months.

The year 1950 saw a number of other important indications of progress in the Terrier program. Following the successful test of the first Lot 0 in February, several quite satisfactory tests were conducted during the year, marking improvements in the missile-borne guidance receiver, beam-riding in the presence of jitter, and successful launching from a trainable launcher to which aiming intelligence was supplied by the guidance radar and computer in order to facilitate missile capture in a moving guidance beam. Of seven Terrier pre-prototypes flown in this period, the one tested on May 12 marked the first supersonic-missile versus target-drone test in this country, while the firing on October 4 proved noteworthy as the first instance of two missiles being fired in salvo. Other units tested included four early Terriers (Lot 1A), of which the first, fired against a target drone on October 18, demonstrated that the new orientation of the steering wings, 45° from the vertical and horizontal planes, gave satisfactory performance. Although several units tested experienced malfunctions that precluded attainment of all prescribed



Exploded view of the BT-3 missile.

objectives, review of the test results for 1950 showed that the sum total of objectives had in fact been attained.

Warhead Development

An important part of the super-accelerated Terrier program was the development of a warhead. Studies indicated that controlled fragmentation of material concentrated in the side walls of the warhead, plus an increase in fragment velocity to 10,000 ft/sec or more, would give twice the killing power per pound of the antiaircraft fragmentation shells previously used. Based on results of experimental work with a hydrogen gun conceived and built at the New Mexico School of Mines under Navy contract, APL became the first proponent and sponsor of high-velocity impact studies. In 1949 a new experimental gun built at the Naval Research Laboratory (NRL) to extend the facilities there for investigation of penetration, in cooperation with APL, obtained velocities believed to be the highest ever achieved with ordinary powder propellants. As a result of studies of the relative merits of small, high-velocity fragments, large fragments (rods) of relatively low velocity, and pure blast, the technique of distributing large numbers of small, fairly high-velocity fragments in an annular conical beam was adopted for use with the Terrier missile.

The effectiveness of a warhead is not alone a matter of the weight of explosive and the type and size of fragments. It depends also on detonation at the precise instant that will cause destruction of the aircraft. This is the fuze's function. Although the development of fuzes for the Terrier missile was a responsibility of the National Bureau of Standards at the time, APL had an important part in determining the width and direction of the channels along which target reflections should be received that would cause the fuze to function.

Studies were initiated to find some means of providing guidance intelligence at low altitude that could not be interfered with by random reflections from the surface. This turned out to be a difficult problem. For another problem, however—that resulting from unintentional friendly-radar interference with the guidance intelligence being transmitted to a missile (or missiles) in flight—a solution was found. With the design of an improved guidance receiver that would accept signals only from its own guidance radar, the problem of unintentional interference from friendly sources ceased to exist.

Advent of the Terrier Missile System

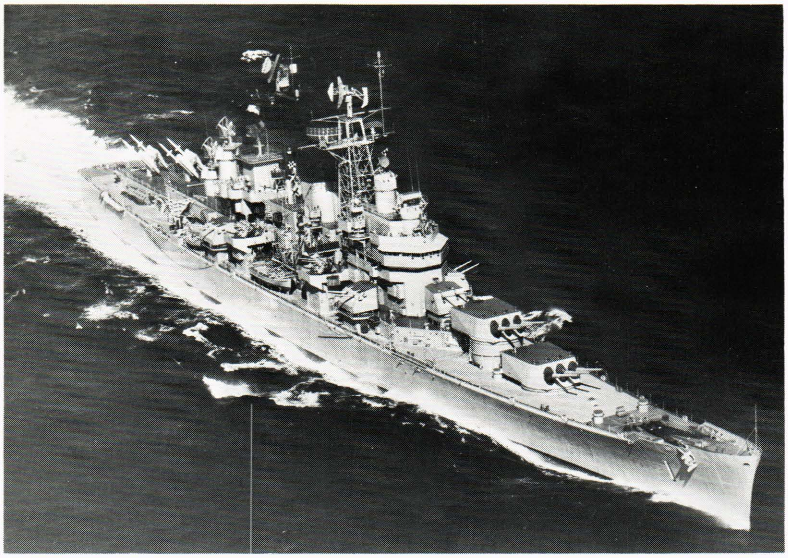
By early 1951, the Terrier program had reached a stage that inspired confidence that an effective weapon system was fairly close at hand. Problems still existed but none was considered insoluble. Moreover, it was felt that corrective measures found necessary could be taken without too seriously disturbing existing designs or schedules. This was most important because the situation could brook no delay; Terrier must be gotten into service as quickly as possible. Reports of bitter fighting in Korea against the staggering odds posed by the entry of 12 divisions of Chinese Communist "volunteers" into the war portended further escalation of the fighting, perhaps even to global proportions.

Most of the problems that lay ahead proved to be of the type normally associated with the transition of a development and engineering program to one of quantity production. But growing confidence that the near future would see a successful antiaircraft guided-missile system in operation encouraged the Navy to make two important decisions early in the year. The first was to start construction of a production facility at Pomona, California, to be devoted entirely to the manufacture of guided missiles. Consolidated Vultee Aircraft Corporation, then constructing the Terrier prototype at San Diego, was selected to operate the new facility. Construction proceeded rapidly, and by the end of 1952 all Terrier manufacturing operations were transferred to Pomona, where they have continued to the present.

The second decision was to have the Navy's Operational Development Force (OpDevFor) conduct an evaluation of the Terrier missile system aboard a combatant ship, following preliminary shipboard tests on the *Norton Sound*. The USS *Mississippi* was selected for this purpose, to be modified by having the two after gun turrets removed and two dual launchers installed. In February 1952, the *Mississippi* entered Norfolk Naval Shipyard for installation of the modified Terrier system—a task completed by the end of the year.

Following this shipyard period, APL assisted in checking out the system elements in the performance of their appropriate functions. November 1952 saw the first missile firings from the ship—two Terrier launching test vehicles that performed satisfactorily to demonstrate operability of the handling, launching, and instrumentation systems. Meanwhile, the heavy cruisers USS *Boston* and USS *Canberra* entered naval shipyards to be converted to Terrier missile ships, destined to become the first guided missile cruisers in naval history.

Mention has been made of the Navy's new operational requirement, issued shortly before the start of the Korean War, and of APL's response to it, leading to the formulation of recommendations for a Terrier of considerably improved performance. As a result of detailed investigations, a beam-riding missile was selected for development, which would include an altimeter-control device for effective guidance at low altitude. Homing was considered also, and design dimensions were selected to accommodate a target seeker. Aerodynamic studies had shown by that time that tail control, in which steering and roll stabilization were accomplished by appropriate movement of tail surfaces, had certain distinct advantages over control through movement of wing surfaces. By the end of 1950 early studies and experimental testing had been completed so that APL was able to prepare a set of preliminary military specifications which formed the basis of recommendations that were accepted by BuOrd in January 1951. This inaugurated a new development program leading to an improved version of Terrier, designated Terrier II.



The USS *Boston* (CAG-1) at sea, showing dual launchers and Terrier missiles on the after deck. (Official U. S. Navy photograph)

Terrier II Program

A test program consisting of four test vehicles (STV–4's) was initiated by APL to obtain verification of the tail control studies. One major change had to be made in configuration. Up to that time the outside diameter of Terrier missiles had been 13.5 inches; it appeared now that it would be necessary to increase the diameter to 15 inches to accommodate a sustainer that could provide the impulse necessary to give the improved performance desired.

By mid-1951, the Terrier II program had suffered considerable delay since it was not permitted to interfere in any way with the "super-accelerated" Terrier I. Further delay in the program seemed a certainty in October 1952, so a six-month review was undertaken. Among other conclusions reached in this review was that a wingless and tail-control version of Terrier, which would have many advantages, could be derived from the original winged design.

Meanwhile, the Terrier I program had made good progress as it swung into high gear at the beginning of 1951. Several excellent tests of Lot 1 and Lot 2 missiles were recorded. The distinction of being the first Terrier to be fired from a ship fell to a Lot 2 missile, which achieved all prescribed objectives in a noteworthy test from the *Norton Sound* on September 7, 1951. Another Lot 2 missile, exactly three months later at NOTS, became the first Terrier to engage an aircraft successfully when its fragmentation warhead scored 15 penetrations in a drone target, although the missile was at the limit of lethality at the instant the fuze functioned. The F6F drone was not brought down by these fragments, but examination showed that one of them passed right through the place the pilot would have occupied had the plane been manned—a hit that would undoubtedly have resulted in loss of the plane. On May 16, 1952, this success was followed by flight tests at NOTS of two Lot 3 missiles fired less than two hours apart at separate drones. Each gave an outstanding performance and destroyed its target. The first Lot 4 missile to be flight tested, in April 1952, proved unsuccessful; this, however, was no cause for great concern because in the desire to make the earliest possible test of several new components a number of modifications to the missile had been found necessary.

It was apparent by this time that because of engineering difficulties Convair was far behind schedule in Lot 4 production. Accordingly, six APL staff members were assigned to Convair to assist in the engineering and production program, while special investigation of a number of components and subassemblies was undertaken at the Laboratory. A few weeks later the Terrier Emergency Committee was established by APL to assume responsibility for all efforts toward a solution of these critical problems.

Aware of the production difficulties, BuOrd in the summer of 1952 selected 30 Lot 4 missiles from the production line, to be designated Parameter Test Vehicles (PTV's) and to be used to check Lot 4 operability and performance in flight, with special attention to the roll problem. The Bureau of Ordnance subsequently formed a Terrier Task Group (TTG) of representatives of the Navy, APL, and associate contractors concerned with the critical problems. This committee took over the functions of the Terrier Emergency Committee and was domiciled at Pomona where it worked closely with Convair's production engineers. As a result of the remedial measures taken, Terrier flight tests in January 1953 showed Lot 4 missiles to be good beam riders, with their reliability appraised as "fair." A test series of Terrier Research Test Vehicles (RTV's) in early 1953 supplied much information of value on overall operability and performance characteristics of Lot 4 missiles and further aided in resolution of the production difficulties at Pomona.

Assurance that Lot 4 missiles could carry out the tasks for which they were designed was strengthened as 1953 progressed. An important milestone was reached in May when a missile fired from the *Norton Sound,* carrying a live warhead, rode the beam to interception and destruction of its F6F drone target. Following closely thereafter was another test at NOTS in which a Lot 4 missile made a successful target interception, marked by proper fuze and smoke puff operation, at an altitude appreciably above that of any previous Terrier test. Eleven days later another of this lot, fired from the *Norton Sound* and armed with a live warhead, destroyed its target, also at high altitude. Such early and convincing demonstrations of the effectiveness of the new tactical Terrier were most encouraging to the Navy, as well as to the Laboratory and its associate contractors.

Of two Lot 4 tests from the *Norton Sound* against targets at low altitude, one was a complete success while the other rode the beam well for 27.5 seconds, then experienced a malfunction of one of the wing controls, the cause of which could not be accurately determined from the test data recorded. All in all, however, on the basis of test performance Lot 4 appeared to be ready for tactical employment at sea. But by this time, the next block of Terriers, designated Lot 5, was in full production. It was not a noticeably different version of Terrier but essentially a continuation of the Lot 4's, incorporating all the design and engineering improvements that experience had dictated in the production and test of its predecessor. The first of this new lot was flown at NOTS in June, a month marked also by the return to Maryland of most of the APL engineers who had been assigned to the Terrier task group at Pomona.

Truce in Korea

The year 1953 witnessed an event of historical importance that gave sanction to a trend that had developed early and almost imperceptibly in the conduct of the accelerated U.S. missile program. The event was the signing of a truce, on July 27, by representatives of the United Nations and the North Koreans, which brought an end to the fighting. The trend was a gradual relaxation of the taut guide lines originally accepted in carrying out the accelerated programs. It was in this atmosphere that the Laboratory began investigations to improve the design of the tactical missile in respect to uniformity and reliability of the production version, without detracting from the main effort.

Recognizing that the early problems had shown a need for engineering improvements to facilitate production, APL initiated a study to demonstrate the feasibility of rearranging missile components so as to simplify assembly, repair, and maintenance. The objective was to group together, into appropriate subassemblies and sections, components that were related either by similarity of technique in manufacture or by test requirements. The new, re-packaged design became known as Terrier IB, to distinguish it from the version then in production, which was based upon the Lot 4 tactical design updated to Lot 5 and labeled Terrier IA.

In April 1953 the Laboratory had prototypes of the re-packaged electronics and hydraulics sections available for examination by the Navy. These were viewed with much favor, and APL was requested to undertake a full-scale engineering program to construct a number of units in order that their performance might be evaluated by extensive ground and flight testing. Two of the newly designed missiles were flown near the end of 1953, after being assembled and checked out with exceptional ease. The first demonstrated excellent beam-riding throughout its long flight, and the second would have done equally well except for a premature smoke puff operation that caused a malfunction in the missile. Additional firing tests were conducted during 1954, with the same or even better success. Laboratory participation in this program terminated in late 1954 when the design was turned over to the Navy, and four missiles were transferred to Convair for evaluation prior to type approval.

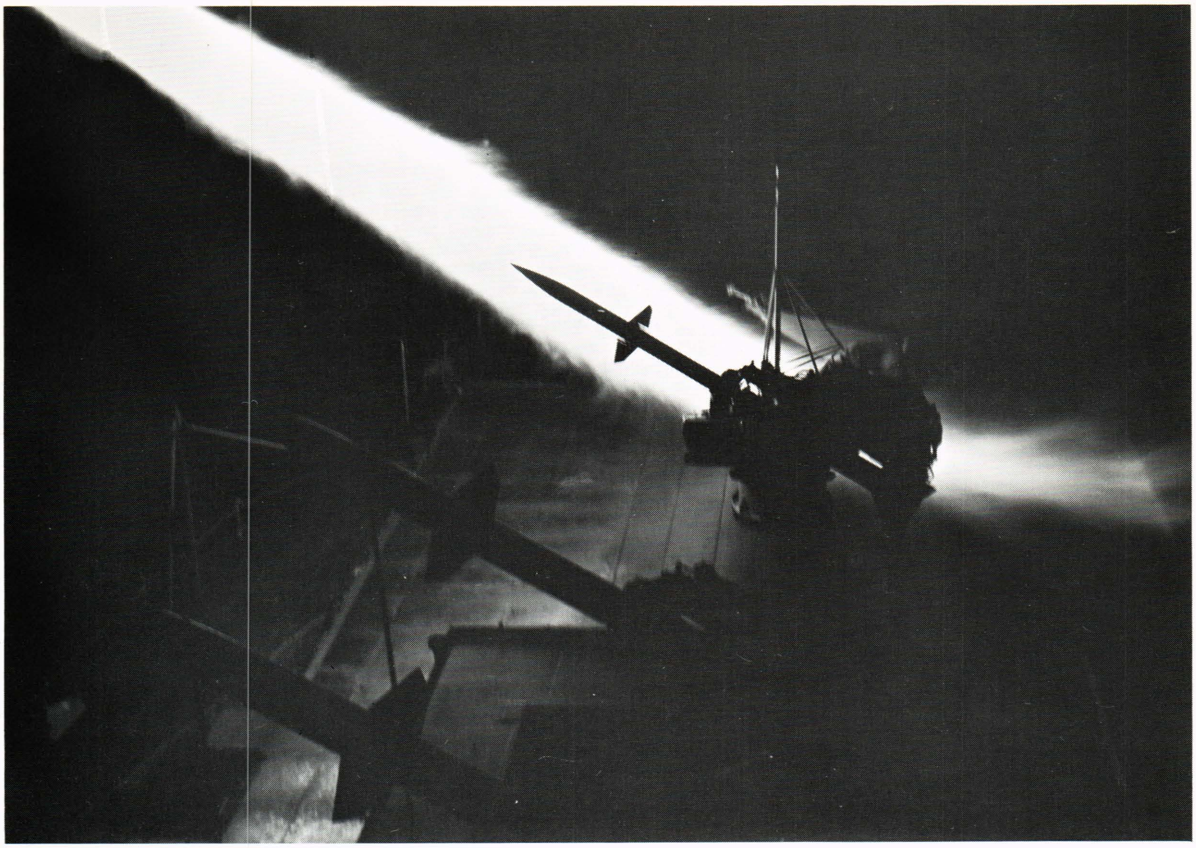
Gradual easing of the tensions that had attended the Korean hostilities also permitted a step-up in the Terrier II (Lot 6) program, the six-month review of which had been completed in the spring of 1953. There were four objectives of this program: (1) to increase missile maneuverability for greater effectiveness against targets at high altitudes; (2) to increase missile range; (3) to permit carrying a heavier warhead to achieve greater lethality; and (4) to improve missile performance at low altitudes. On the basis of the program review, a new set of performance requirements was prepared by APL, and BuOrd contracted with Convair to engineer and develop a group of eight test vehicles, designated STV–5s, for flight test under APL's technical direction to determine their ability to meet these requirements.

On July 1, 1954, the OpDevFor evaluation of the Terrier missile system began, following completion of the BuOrd Assist Phase that had been conducted aboard the *Mississippi* to familiarize personnel of the ship with the new weapon system.

Missile Modification Program

As the engineering program undertaken first by APL in 1953, then by Convair, made progress in 1954 toward a better tactical Terrier, the introduction of changes in the roll system, hydraulic power supply components, aerodynamic surfaces, and other improved components required retrofitting of missiles on a systematic basis. Accordingly, a step change in missile production was adopted by which such improvements could be incorporated when they were found to be ready for use in production missiles. At the same time the necessity of differentiating between the types of missiles being produced became apparent. It was decided, therefore, that the required designations would be made up of two letters each, the first indicating the method of guidance and the second, the method of control. For guidance, B would indicate beam-riding and H, homing. For method of control, W would indicate wing control and T, tail control. The number 1, 2, or 3 following these letters would identify the combination of booster and sustainer rockets used by the particular missile. The then-current production missile was assigned the designation BW-O, indicating that it employed the combination of booster and sustainer rockets then in production.

Work on homing guidance was actively continued during this period. As early as 1953, good results had been obtained with the Raytheon target seeker used in Sparrow—one of the super-accelerated missiles of the Korean emergency period—and it was closely watched for possible application to Terrier. Under APL sponsorship Convair established a facility on San Clemente Island, off the California coast, to obtain basic



Terrier missiles undergoing test firing at sea from the deck of the USS *Mississippi*.
(Official U. S. Navy photograph)

measurements of sea reflection properties having effect on homing guidance, and to evaluate seekers, such as the one used in Sparrow, for possible service in Terrier. Data recorded there were converted into suitable form to be used in the Raytheon seeker when tested in homing simulators built by Convair.

Late in 1954, the Laboratory began a three-phase program of development of a semiactive homing system for use in Terrier I missiles. Test firings that began in early 1955 and continued for about two years demonstrated the feasibility of homing guidance as well as its effectiveness against low-flying targets.

There were in effect during the latter part of 1953 and all of 1954, two Terrier development programs in addition to the still-basic program of proving-in the tactical Terrier I missile. The first of these development programs was the Terrier improvement program, which had as its objective improvement of the tactical missile through engineering changes designed to simplify missile assembly, checkout, and repair, and to develop effective guidance at low altitude, without seeking to extend the missile's performance beyond that prescribed in pertinent specifications. The second was the improved-performance Terrier (designated Terrier II), which had as its objective the development of a missile with substantially increased performance capabilities in range, altitude, and maneuverability, plus improved effectiveness at low altitude.

Advanced Terrier

From consideration of these two development programs as 1954 advanced, it could be said that they had a common purpose in the sense that both were directed toward achievement of a service missile that would give consistently excellent performance within its designed limits, be easy to produce and maintain, and possess a high degree of adaptability to meet various situations. Certain design and engineering developments in each program were found to be applicable and beneficial to the other. Accordingly, APL and Convair late in the year formulated a long-range program for improvement of the Terrier missile, which was submitted to BuOrd for approval. Its objective was to achieve production by 1960 of an "Advanced Terrier" missile that would be compatible with the stowage and handling facilities being installed for Terrier I in the heavy cruiser missile ships and would be capable of successful interception and destruction of potential air threats in that period.

Development of Advanced Terrier was to be based on the sectionalized configuration of the Terrier IC, then entering the flight-test phase of evaluation, and on the knowledge gained from the Terrier II program of the performance that could be reasonably expected from the wingless, tail-controlled missile. A stepwise development was planned, therefore, so as to have in the production stage at any given time a missile capable of countering the potential threat for that period.

On the basis of this review, BuOrd early in 1955 redirected the Terrier II program along the lines summarized above, assigning technical direction to APL. Although the program of developing an improved-performance Terrier took on a somewhat different hue as a result of this redirection during early 1955, the test results obtained up to that time in three STV–4 firings contributed substantially to the STV–5 program. Much useful data were obtained. The third STV–4 test confirmed studies that a wingless missile would be both feasible and practical, thereby contributing in large measure to the decision to eliminate wings on all improved-performance Terriers.

Planning started at once on the Advanced Terrier program. A homing-guidance Terrier, to be designated HT–3, was made the ultimate objective of the program, but since development of homing guidance had not progressed as far as that of beam-riding guidance, some doubt existed that missiles employing a homer would be ready for production as early as 1960. It was decided, therefore, to develop the necessary aerodynamics, dynamics, control, and propulsion systems in a beam-rider (BT–3) that could be available by 1960, and then to utilize these developments in a homing missile design when a suitable system of this type was developed. By so doing, maximum use could be made of Terrier BW–1 developments in the areas of guidance, warheads, and fuzes, as well as of the STV–5 series of missiles. The firing of two launching test vehicles and four control test vehicles in this series contributed data that were to prove useful in the advanced program.

First Guided Missile Heavy Cruiser

The ultimate aim of the years of effort in Terrier development was brought a long step closer to realization on November 1, 1955, when the USS *Boston,* having successfully completed the required preliminary acceptance trials, was recommissioned at the U.S. Naval Base, Philadelphia. Its name was unchanged but it bore a new Navy classification, CAG–1, signifying the first of a new class of ship in the U.S. Navy (and in world history)—"guided missile heavy cruiser."

On January 30, 1956, after several weeks devoted to familiarization with the new weapon system, the *Boston* sailed for Guantanamo to undergo shakedown training. There, early in February, the prescribed training began, which, because of the revolutionary weapon system installed in the ship, was extended beyond the usual six weeks. Several important groups of visitors witnessed the missile firings, spanning a period in which 10 Terriers, in the jargon of Navy torpedomen, flew "hot, straight, and normal" to successful achievement of all objectives.

As of July 1, 1956, the development phase of Terrier I was considered to be complete. Terrier had gone to sea.

PUBLICATIONS

The following list is a compilation of recently published books and technical articles written by APL staff members.

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S. D. Bruck, "Thermal Degradation of an Aromatic Polypyromellitimide in Air and Vacuum—III—Pyrolytic Conversion into a Semiconductor," *Polymer* (London), **6,** July 1965, 319–332.

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D. J. Williams (APL) and G. D. Mead (NASA), "A Nightside Magnetosphere Configuration as Obtained from Trapped Electrons at 1100 Kilometers," *J. Geophy. Res.,* **70,** July 1, 1965, 3017–3030.

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D. Abraham and T. O. Poehler, "Heat Flow as a Limiting Factor in Thin-Film Devices," *J. Appl. Phys.,* **36,** June 1965, 2013–2020.

The following five papers were published in *Tenth Symposium (International) on Combustion,* The Combustion Institute, Pittsburgh, Pa., 1965:

W. G. Berl (APL), P. Breisacher (Aerospace Corp.), D. Dembrow (NASA), F. Falk, T. O'Donovan, J. Rice, and V. Sigillito (APL),